# Evaluation of NASA GISS GCM Simulated Cloud and TOA Radiation Budget using CERES-MODIS Observations

Xiquan Dong, Ryan Stanfield, Baike Xi, Aaron Kennedy
University of North Dakota

Tony Del Genio, NASA GISS

Patrick Minnis, Dave Doelling, Norman Loeb, NASA Langley Research Center

# Motivation

To better advise policymakers, it is necessary for climate models to provide credible predictions of future climates. Meeting this goal requires climate models to successfully simulate the present and past climates.

The past, current and future Earth climate has been simulated by the NASA GISS ModelE climate model and has been summarized by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, AR4, 2007).

New simulations from the updated AR5 version of the NASA GISS ModelE GCM just released to the public community during summer 2011 and will be included in the IPCC AR5 ensemble of simulations.

Due to the recent nature of these simulations, however, they have yet to be extensively validated against observations.

# Objectives

1. Compare the NASA-GISS AR4 and AR5 GCM simulated global cloud fractions with CERES-MODIS Observations

2. Evaluate the NASA-GISS AR4 and AR5 GCM simulated TOA radiation budgets, as well as investigate the impact of clouds on TOA radiation budget.
   - ➔OLR – Outgoing Longwave Radiation
   - ➔Albedo
   - ➔Net Flux

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# Datasets

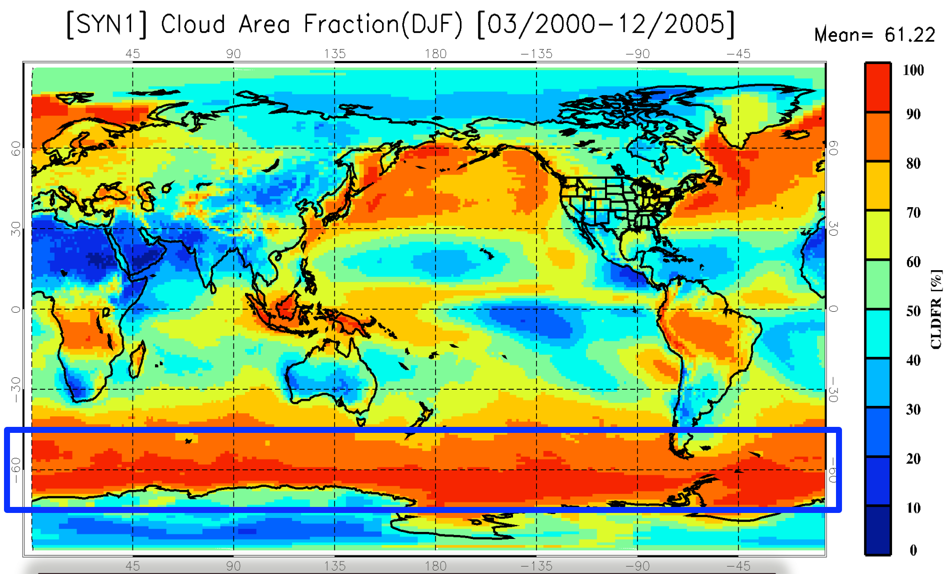
**SYN1 – NASA CERES-MODIS Observations**
**1ºx1º (Lat x Lon) Resolution [03/2000 – 12/2005]**
**Observations are temporally interpolated and fit to data from geostationary satellites.**
**Aqua and Terra observations were combined.**

**AR5 – NASA-GISS GCM**
**2ºx2.5º (Lat x Lon) Resolution [03/2000 – 12/2005]**
**Data downloaded from CMIP5 (Coupled Model Intercomparison Project Phase 5)**

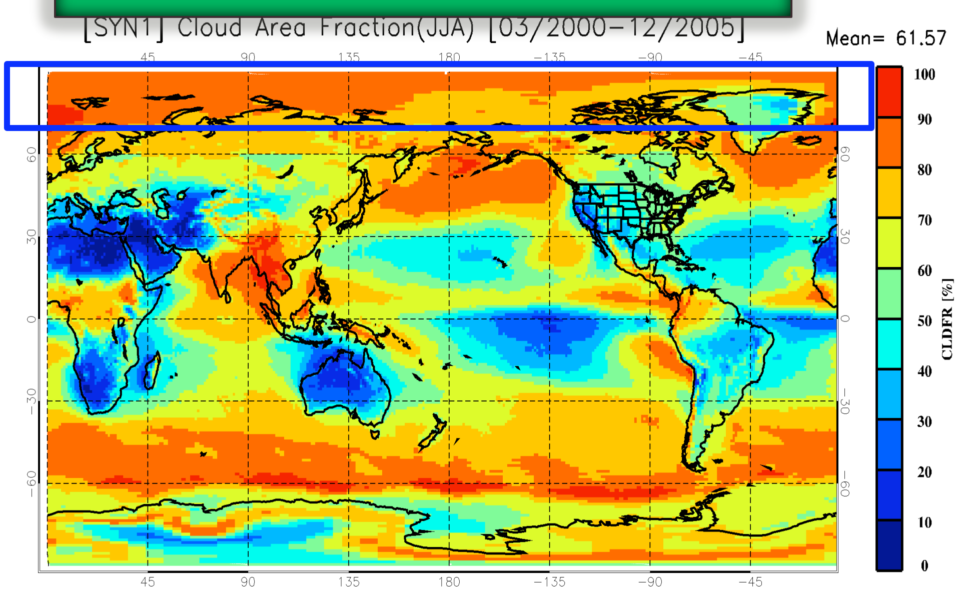
**AR4 – NASA-GISS GCM**
**4ºx5º (Lat x Lon) Resolution [03/2000 – 12/2003]**
**Data downloaded from CMIP3**

# Cloud Fraction-Observations

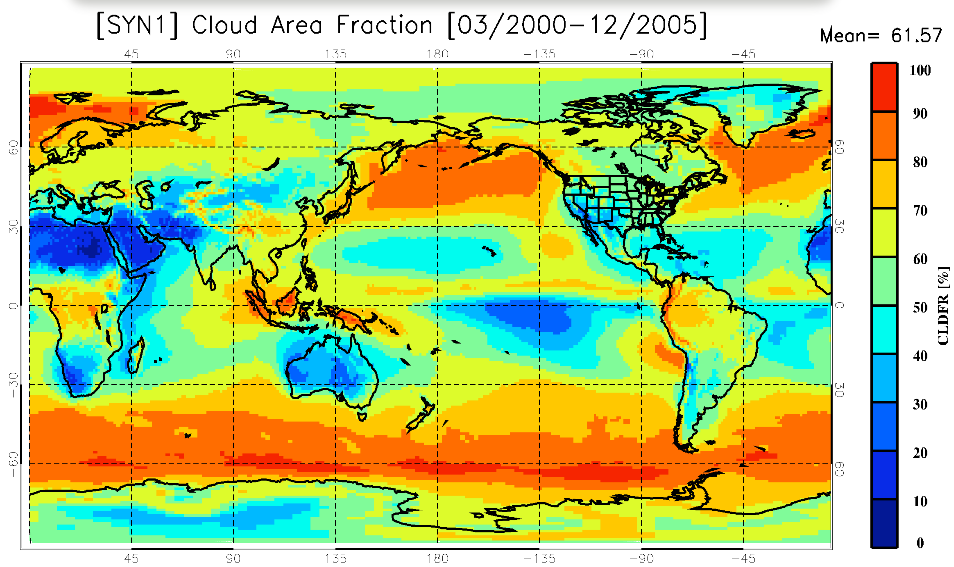
## Winter - DJF




## Summer - JJA




## Year



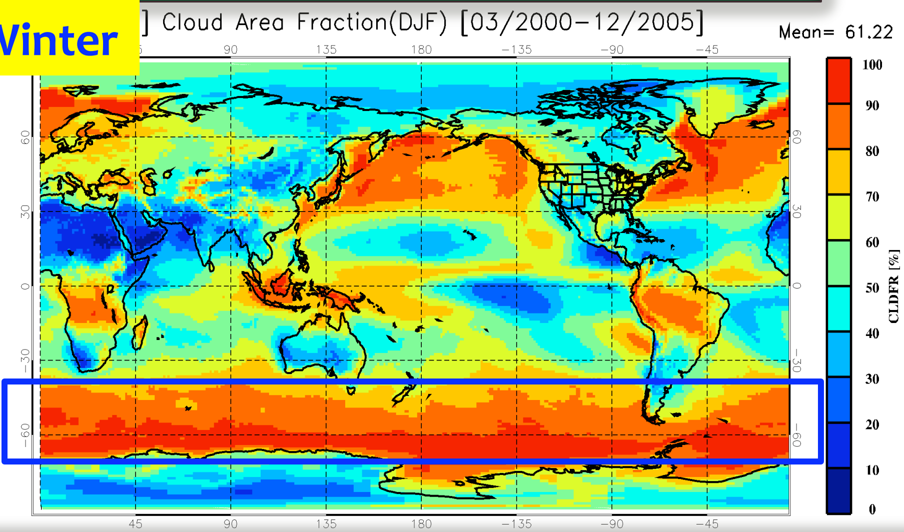

The global CFs of annual, winter and summer are nearly the same (61%).
During Winter, more clouds over Southern Mid-latitudes.
During Summer, more clouds over Arctic.

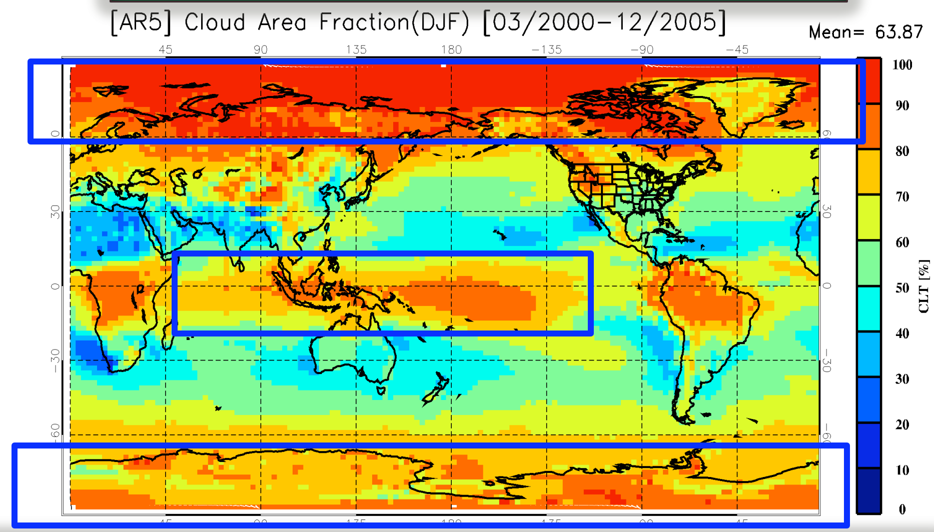
# Comparison of Cloud Fraction between Observations and Model Simulations

## Observation – SYN1

## Model – AR5

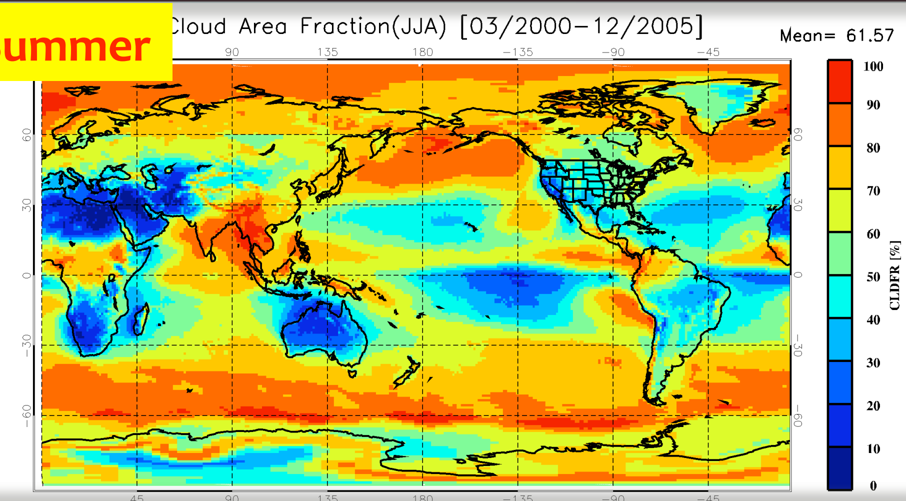
**Winter**

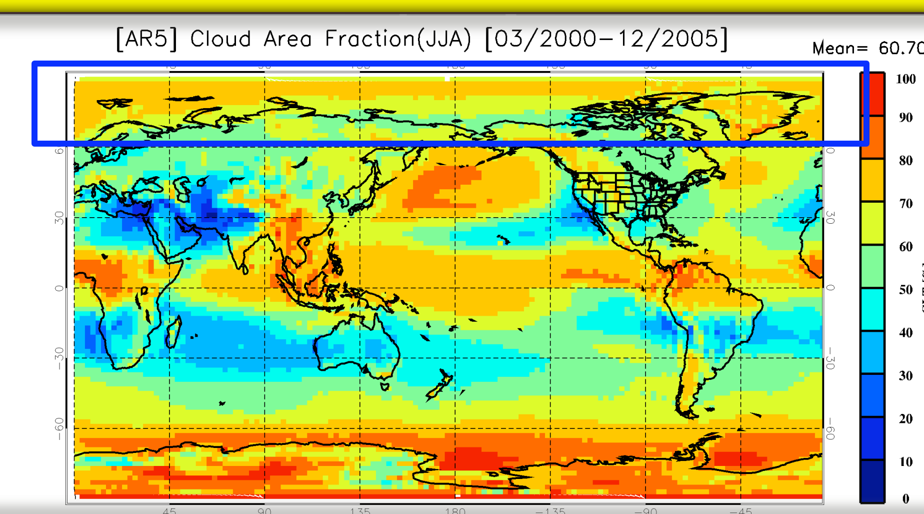



**Model overestimated CFs in Polar and Tropics, but underestimated CF in Southern mid-lat.**

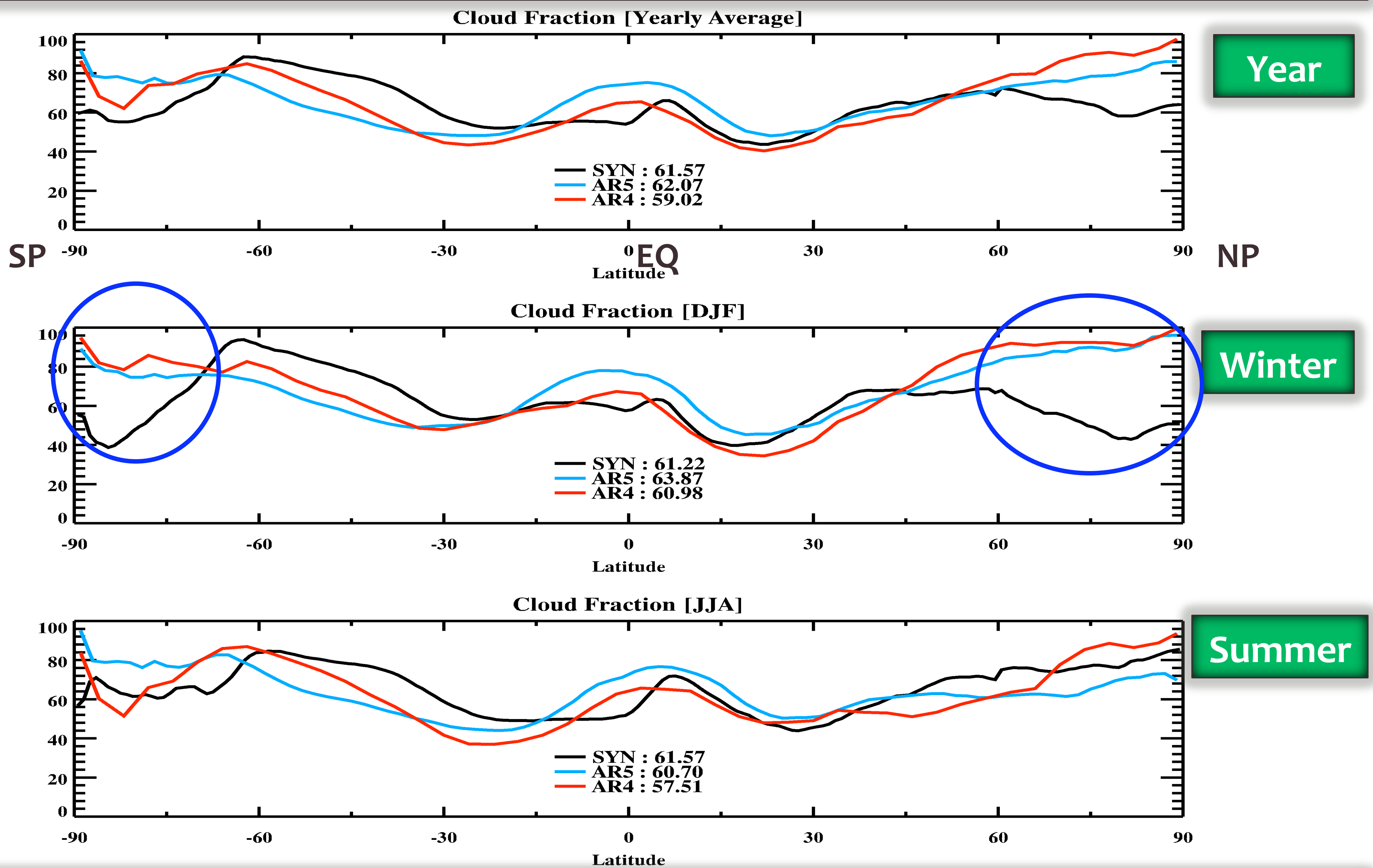
**Summer**



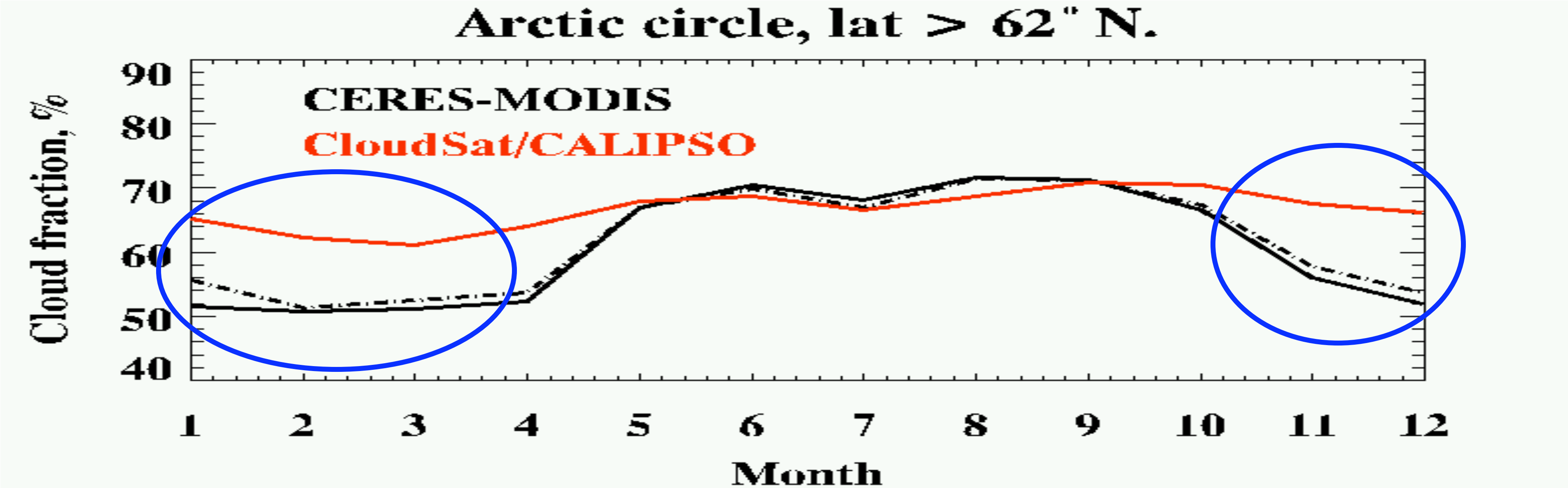




**Same as winter comparison, such as model overestimated CFs in Tropics, Sahara desert and Antarctic, underestimated CF in Southern mid-lat (and Arctic region-only difference).**

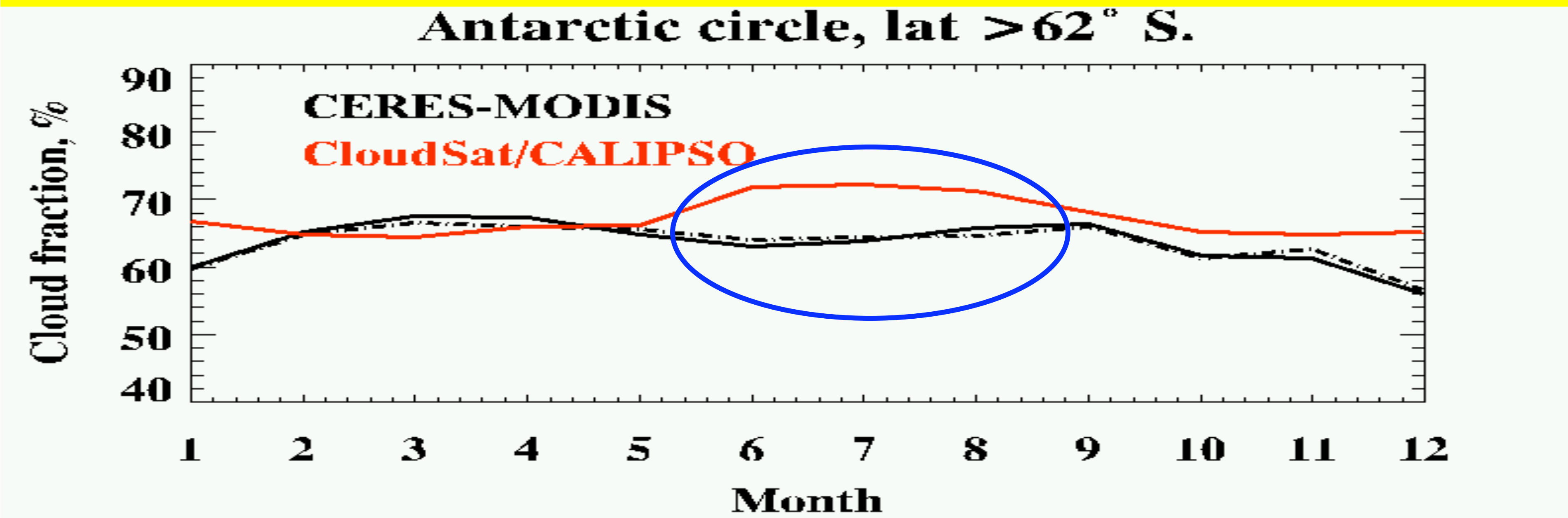
# Latitudinal CF Comparison between CERES-MODIS, AR4 and AR5




The modeled mean CFs agree with observations within 1-4%, but significantly overestimated CFs over Polar regions. Is this difference due to passive MODIS remote sensing limitation?

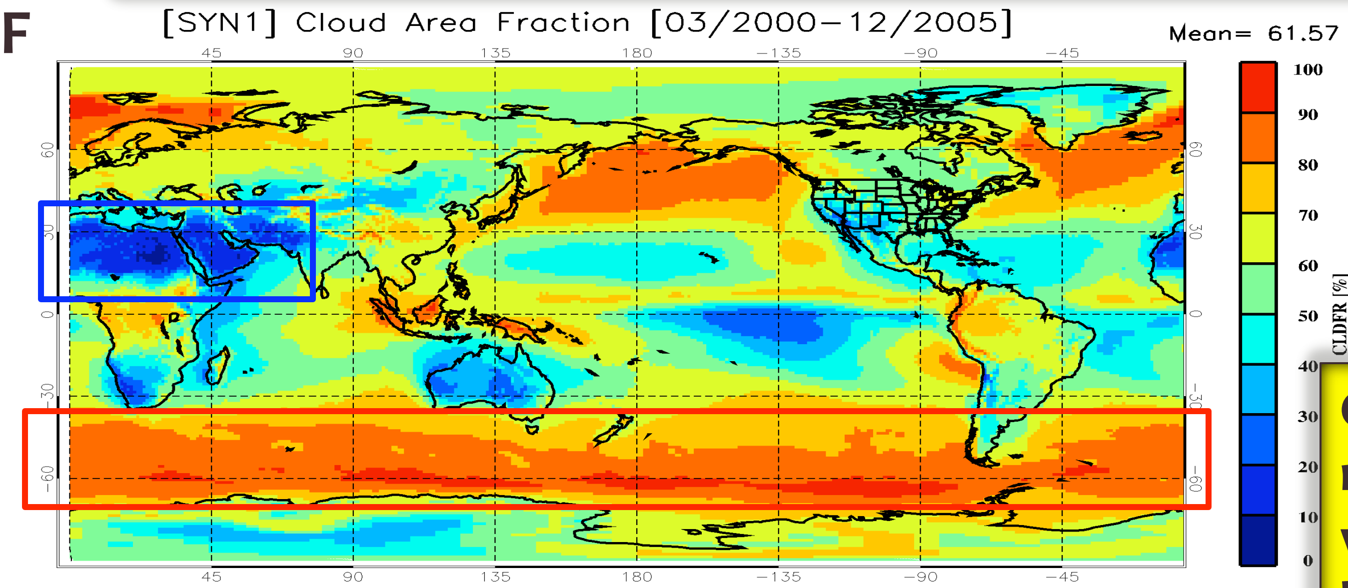



CLoudSat/CALIPSO observed CFs are higher than CERES-MODIS observations during Polar Nights over Arctic and Antarctic regions, but no as high as AR4 and AR5 simulations (>80%).

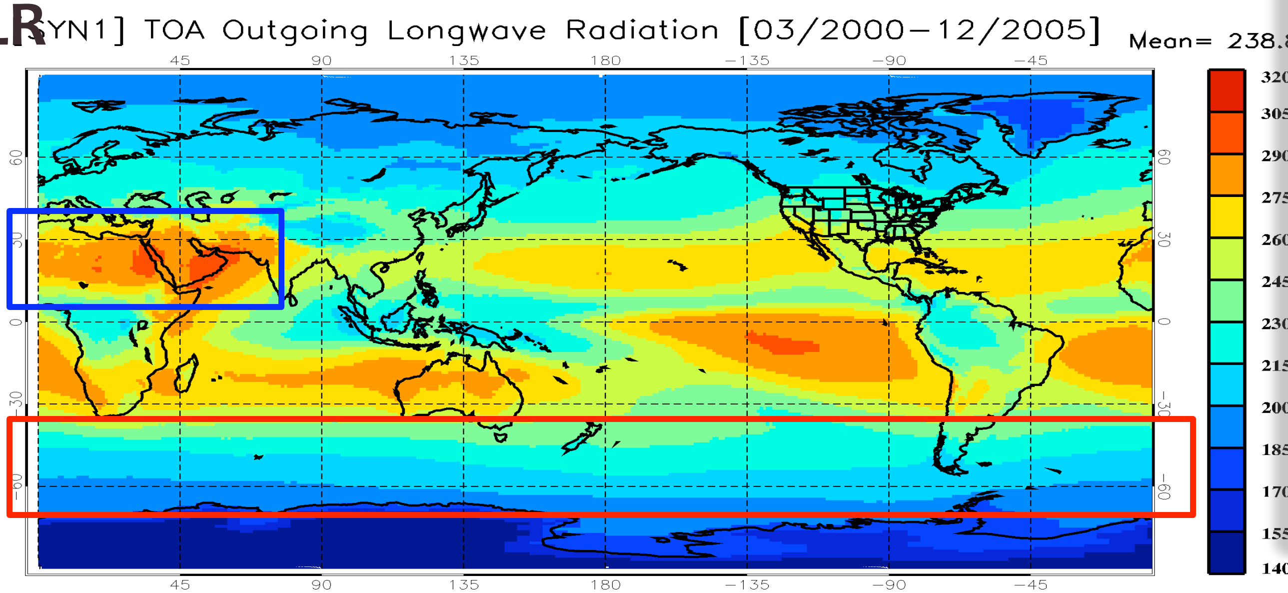


# Observed OLR and CF by NASA CERES

CF




OLR




OLR has a strong negative relationship with CF (particular for high-level CF):

More CF ➔ Cloud-top temp cooler than surface ➔Less OLR

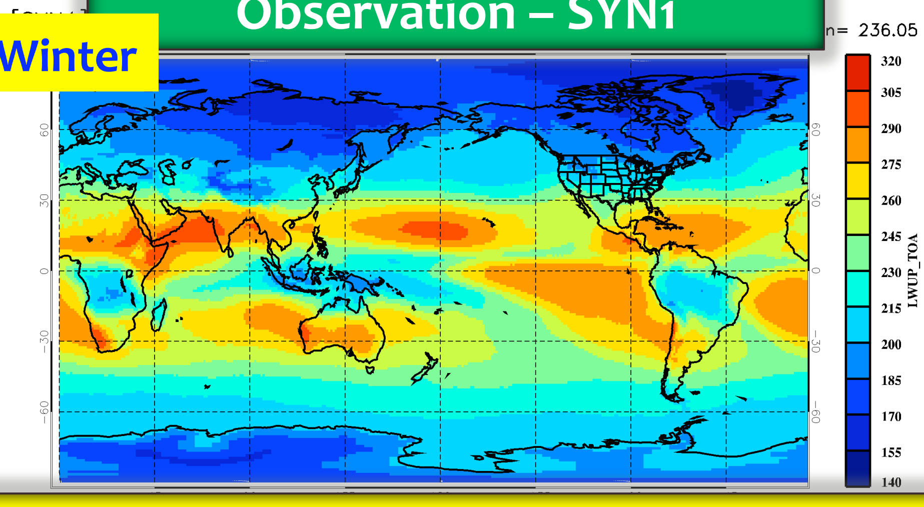
Less CF ➔Higher surface temperature ➔More OLR

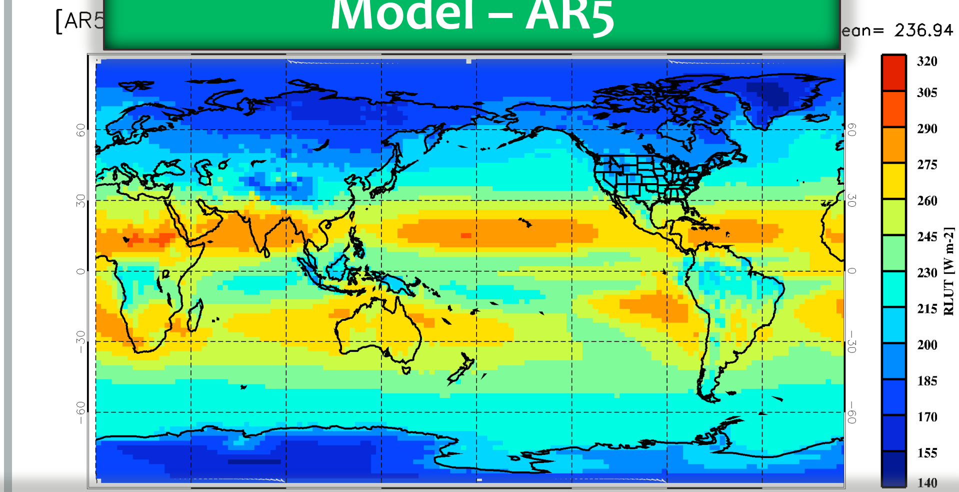
# Comparison of OLR between Observations and Model Simulations

## Observation – SYN1

## Model – AR5

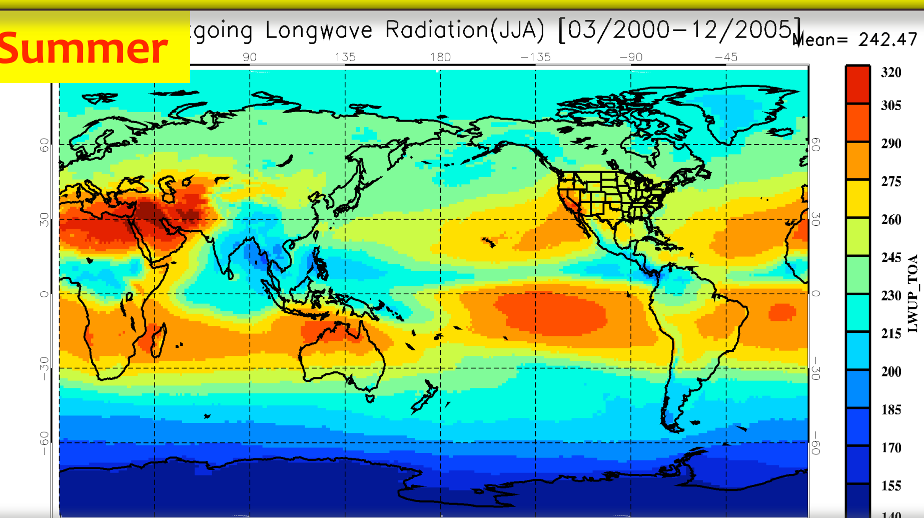
**Winter**

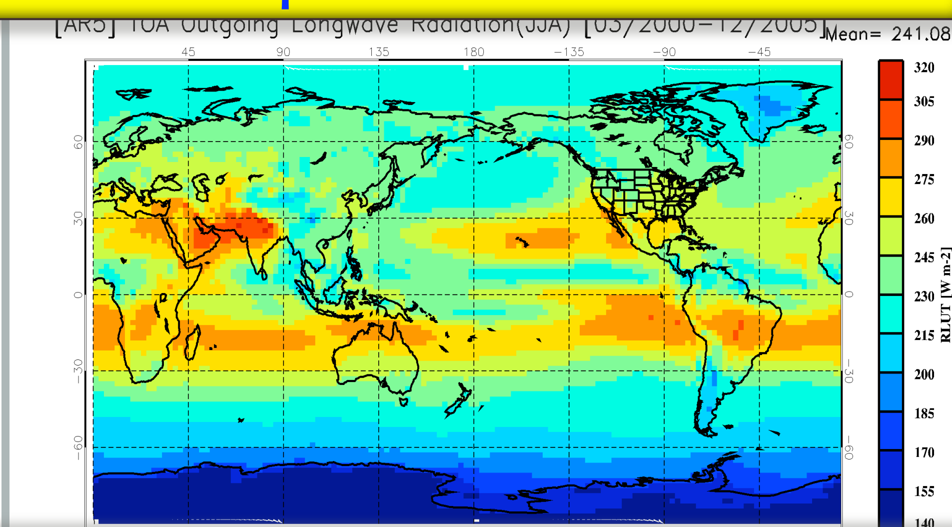



**Modeled OLR agrees well with CERES observation even though the CF differences existed in Arctic, Tropic, and Southern Mid-Lat➔Compare different levels of CFs.**

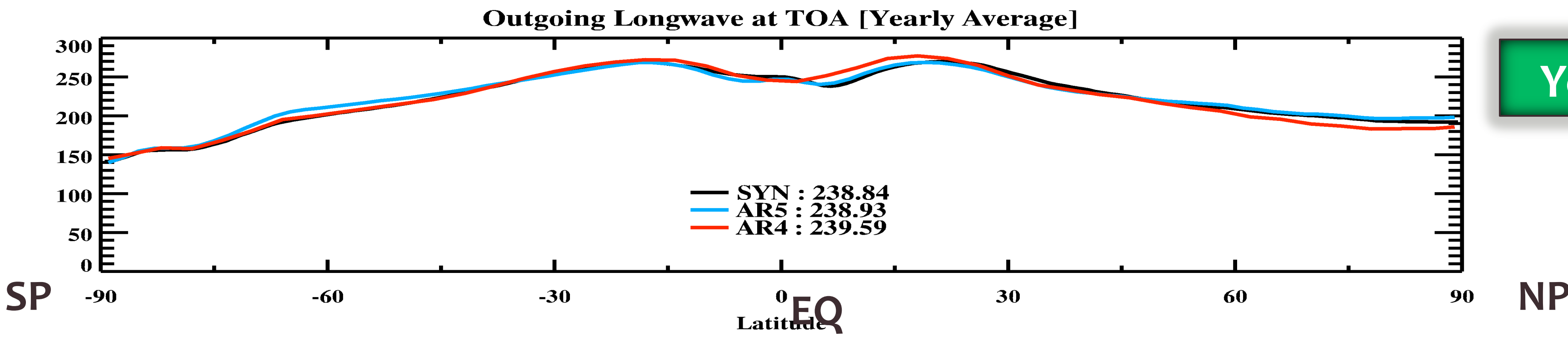
**Summer**



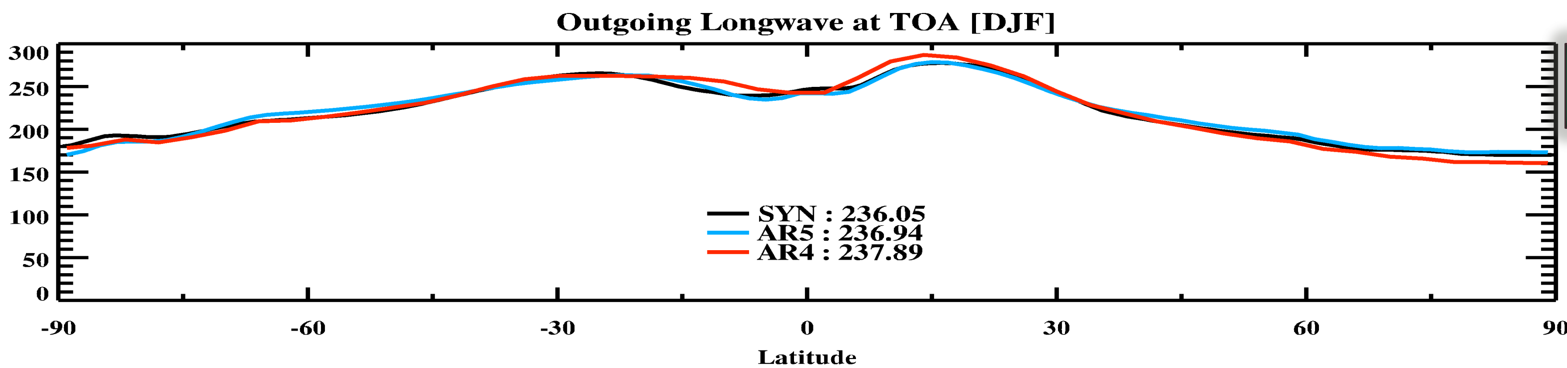




**Model overestimated CFs in Tropic and Sahara desert, thus its modeled OLRs are Less than CERES observations.**

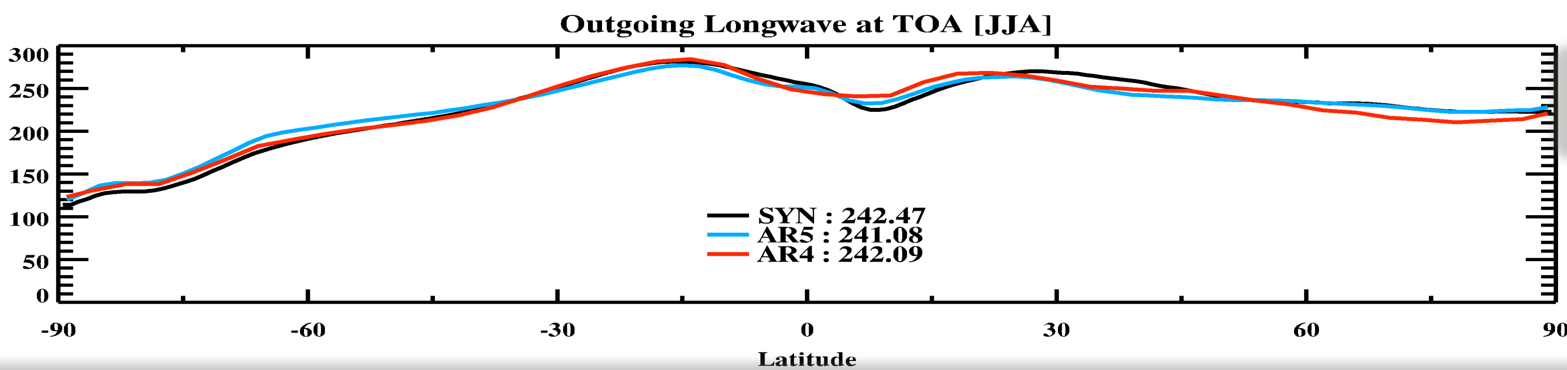
# Latitudinal OLR Comparison between CERES, AR4 and AR5




Year




Winter

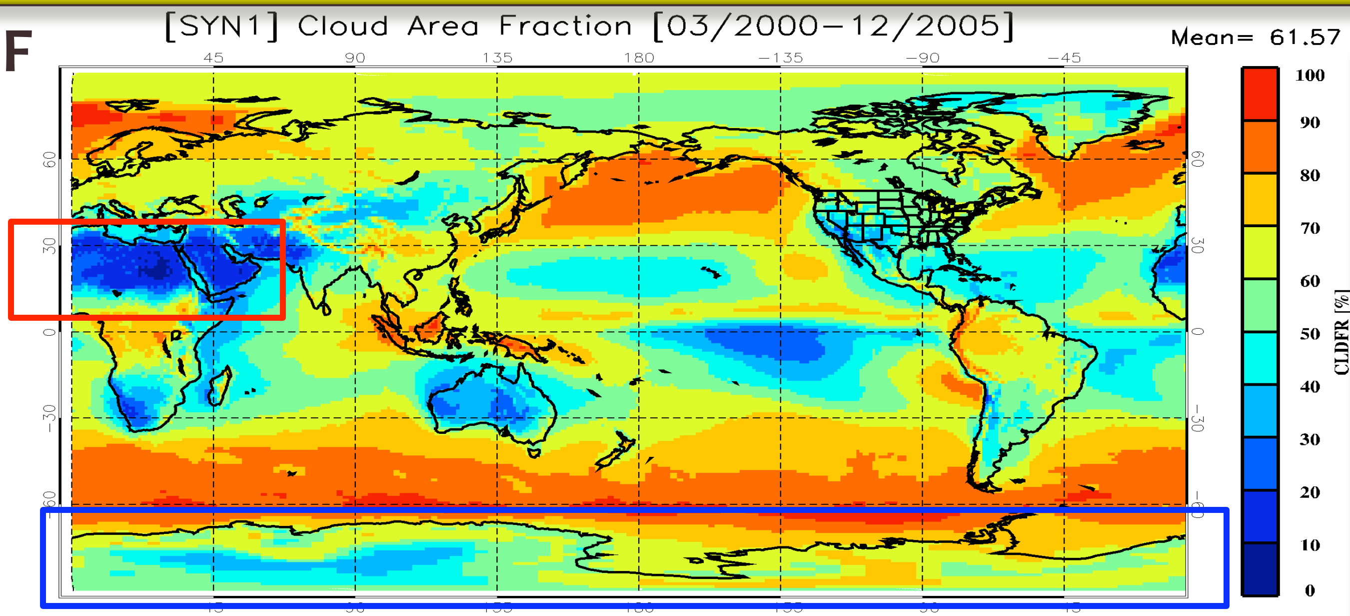



Summer

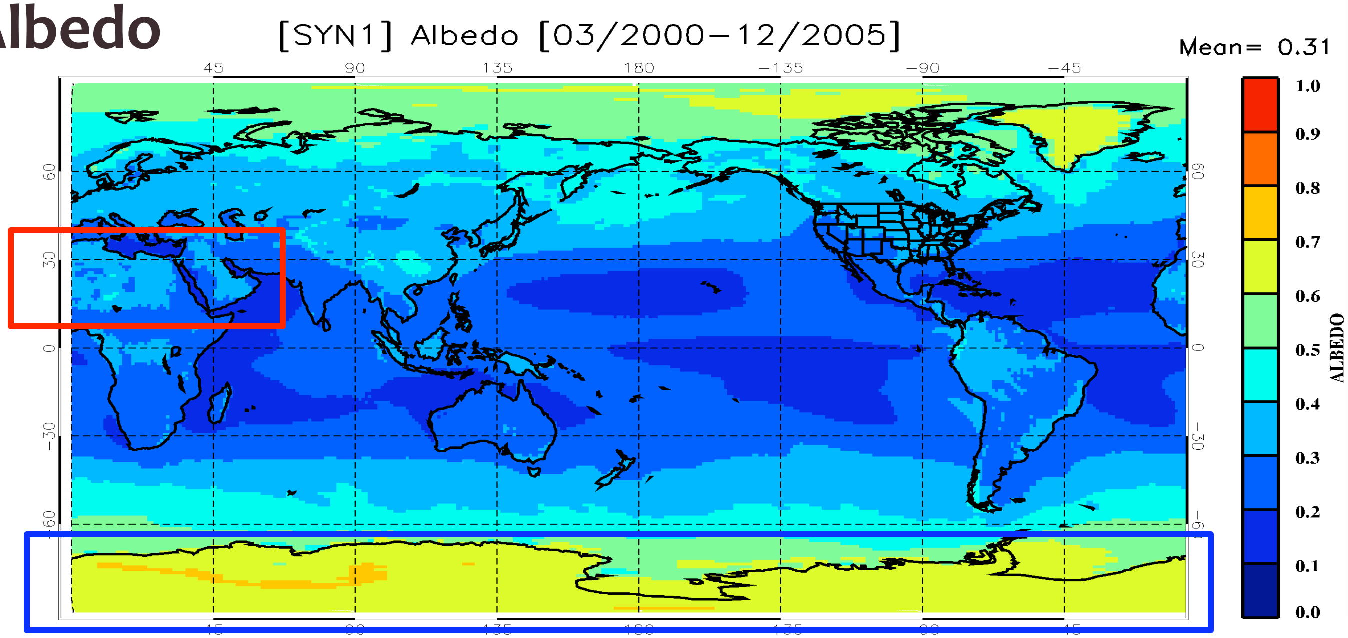
Excellent agreement between CERES observations and AR4 and AR5 simulations although there are some differences over several regions. This is the reason we should compare them regionally.

# Observed TOA Albedo and CF by NASA CERES

CF




Albedo




TOA albedo has a strong positive relationship with CF:
More CF → higher TOA albedo
Less CF → lower TOA Albedo

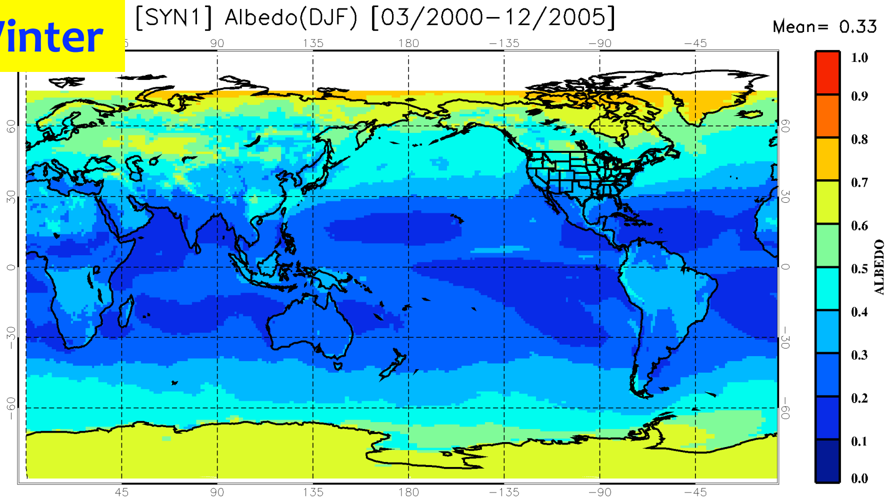
Except for Sahara desert and Polar regions:
Desert surface reflection is much higher than other surfaces.
Snow/ice surface reflection is close to cloud reflection

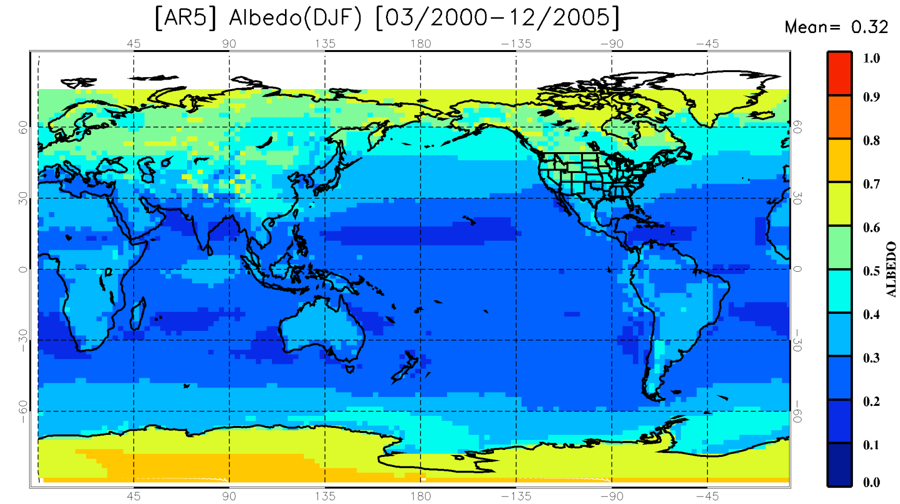
# Comparison of Albedo between Observations and Model Simulations

## Observation – SYN1

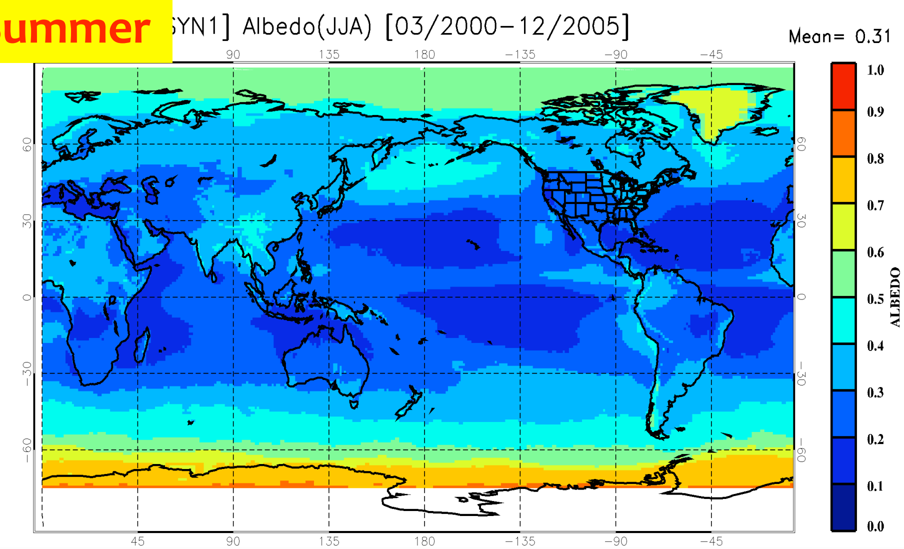
## Model – AR5

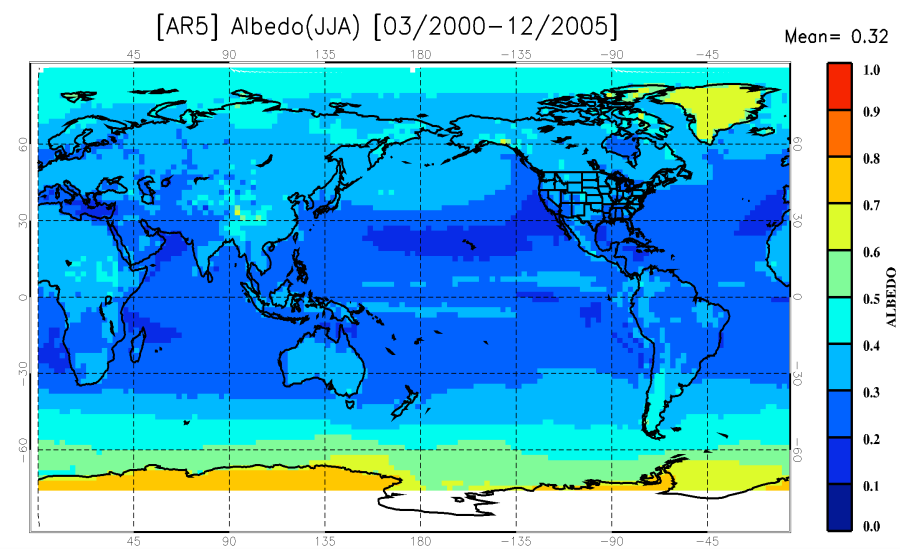
**Winter**



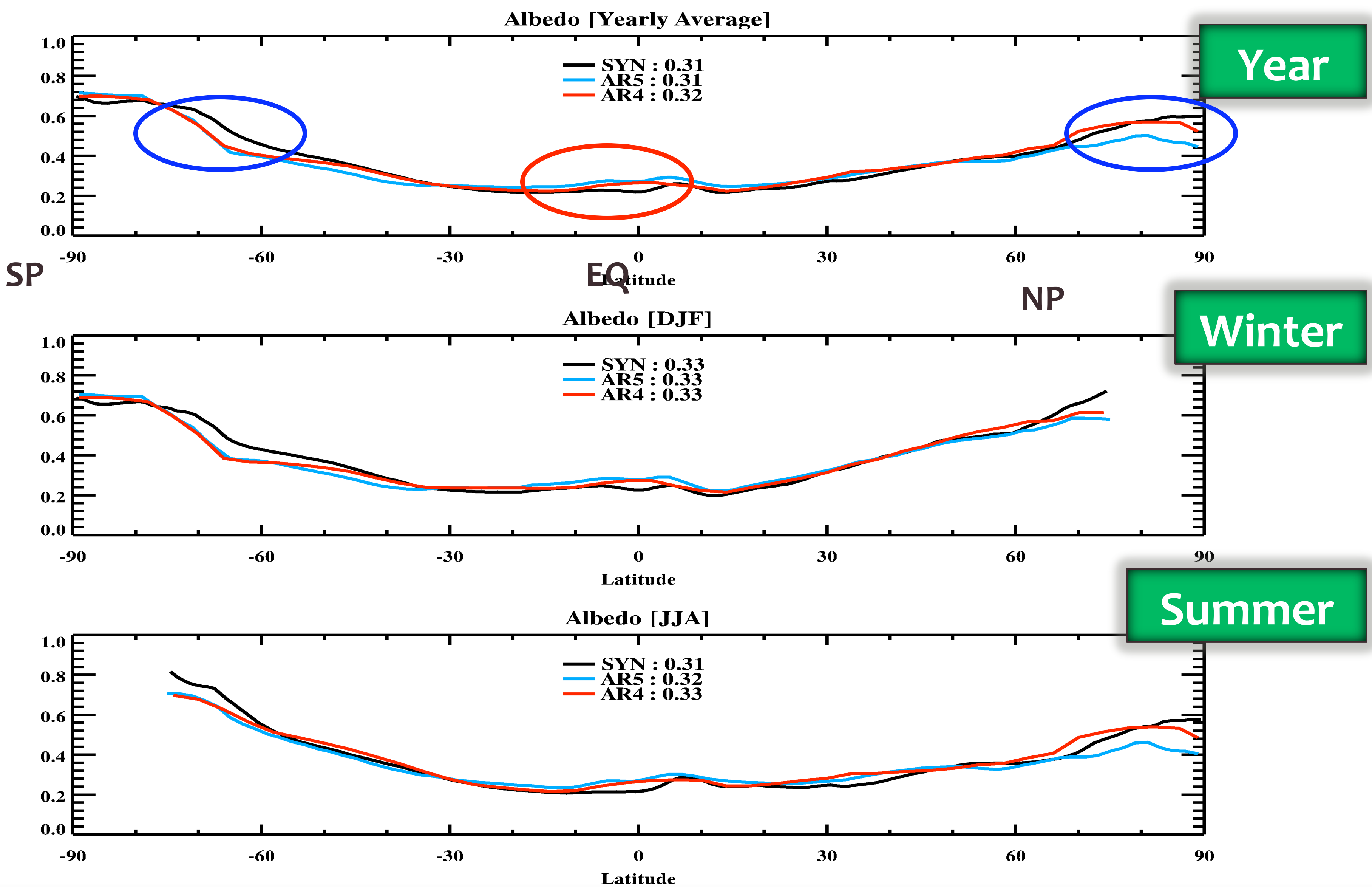

**Summer**



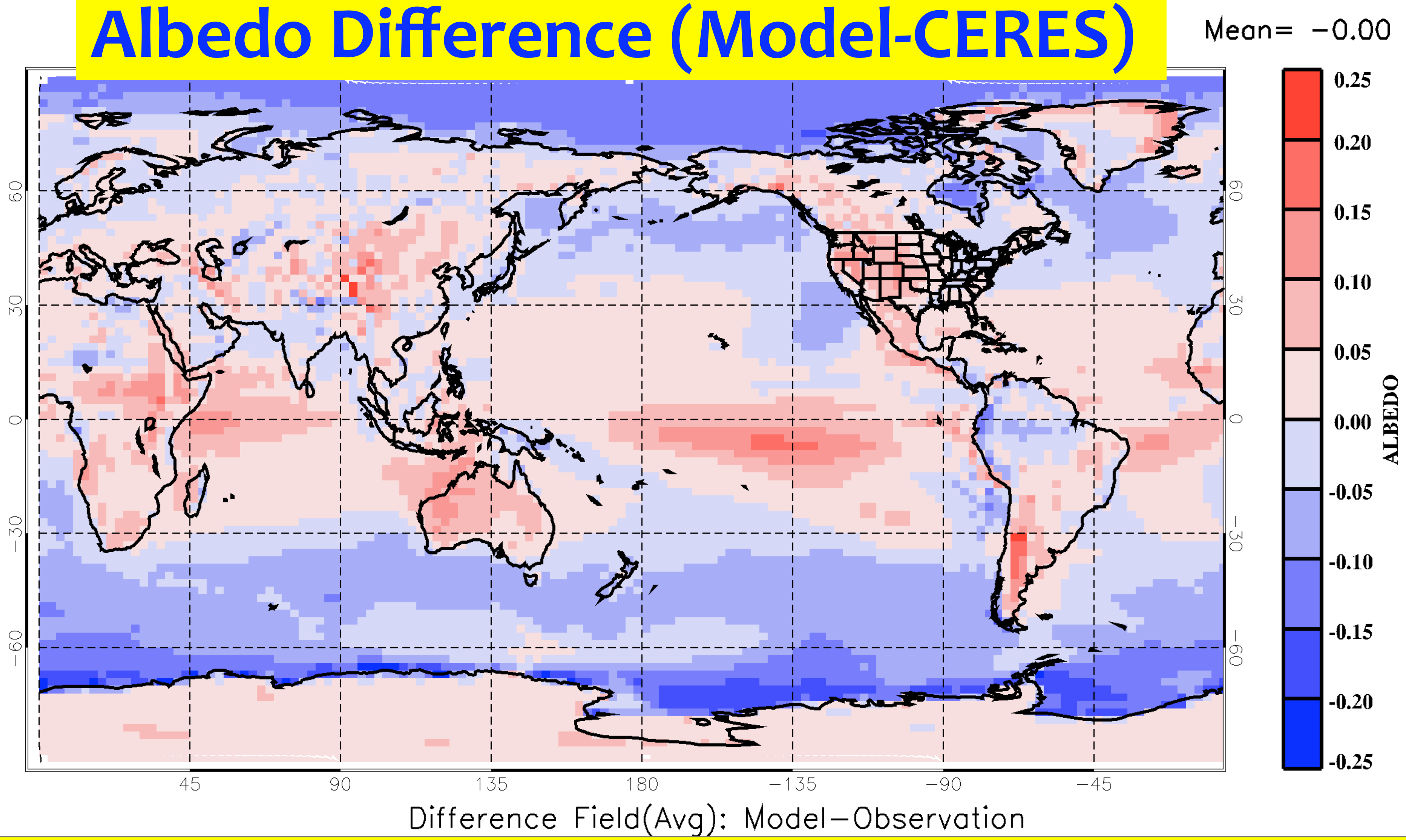

**The global means are the same (0.32), differences exist in some regions, in particular over Arctic regions during Summer months.**

# Latitudinal Albedo Comparison between CERES, AR4 and AR5




AR4 and AR5 simulated TOA albedos agree well with CERES observations except for AR5 simulated albedo is higher in Tropics and lower in Arctic and S. Mid-lat

# Albedo Difference (Model-CERES)

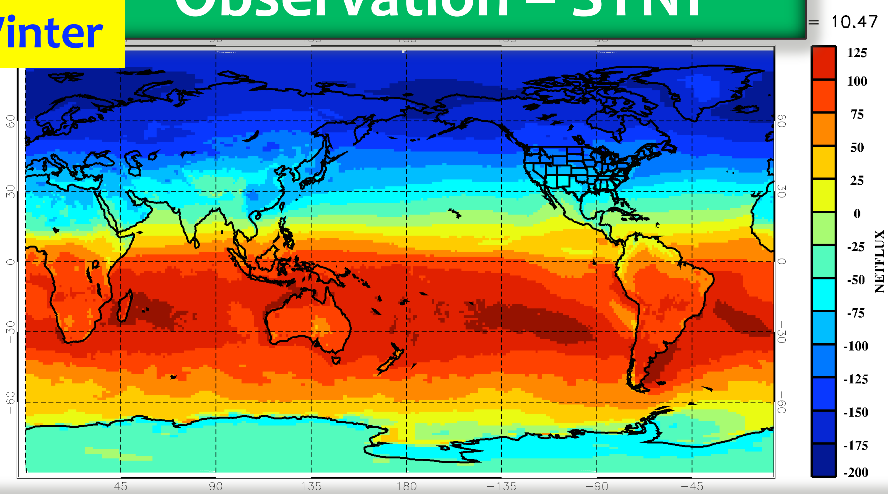


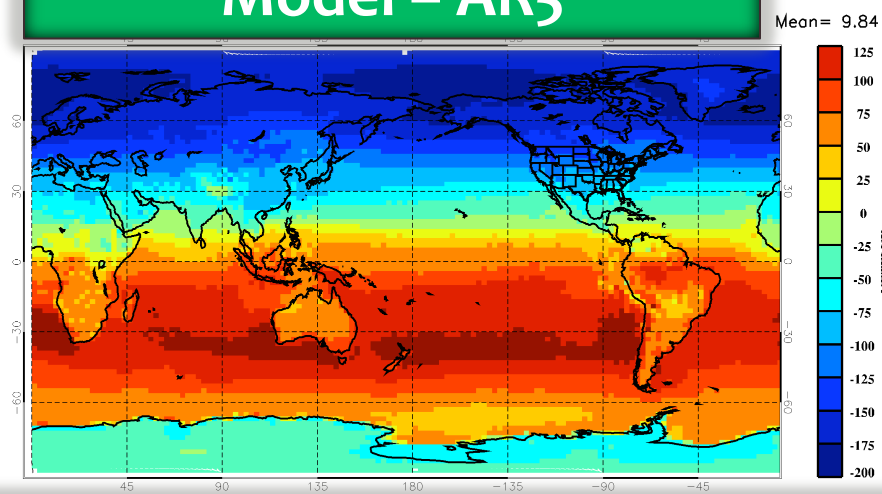

**"To keep the global radiation balance at NASA GISS GCM, we have to tune our model's albedo higher in Tropics. This is an example of a problem that GCM groups (NCAR and GFDL) have been aware of for a long time. But solving it is difficult - it depends on a good simulation of ocean boundary layer clouds, which is very hard to do (or else we would have solved it already)." ~Anthony Del Genio**

# Comparison of Net Flux between Observations and Model Simulations

## Observation – SYN1 | Model – AR5

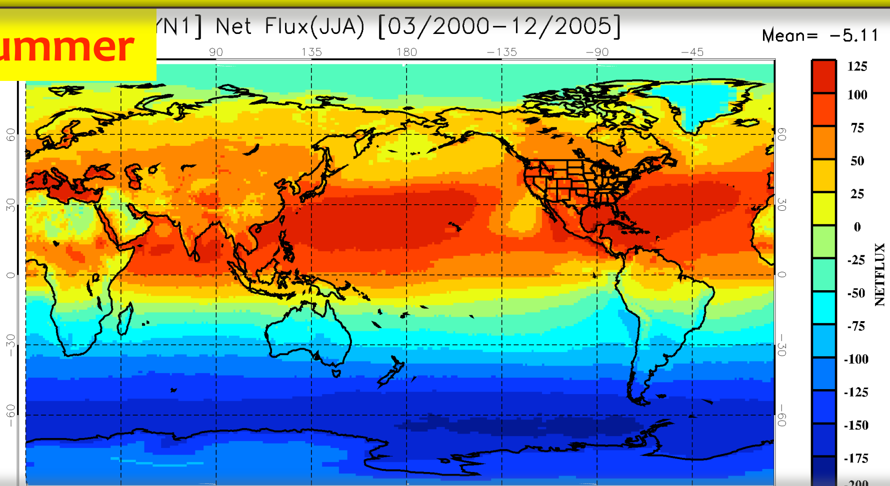
**Winter**

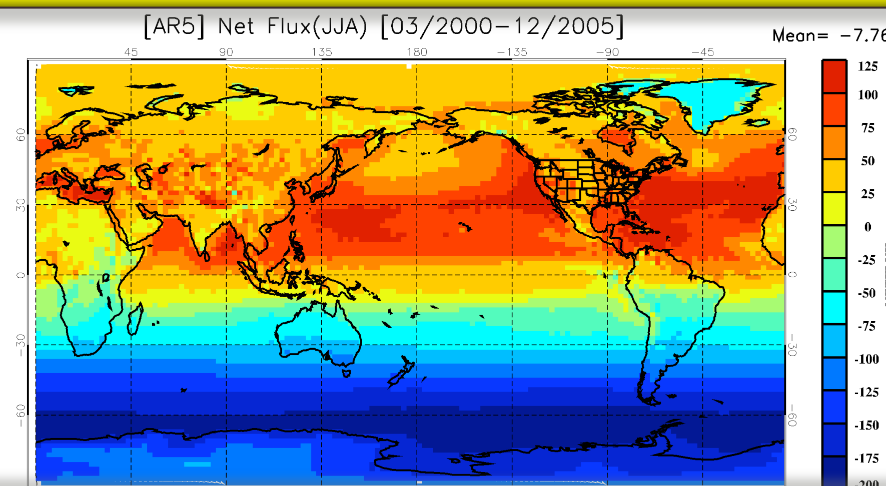



In general, modeled net flux agrees well with CERES observations, their global difference is 0.63 $Wm^{-2}$. Slight differences over tropical and Southern mid-Lat.

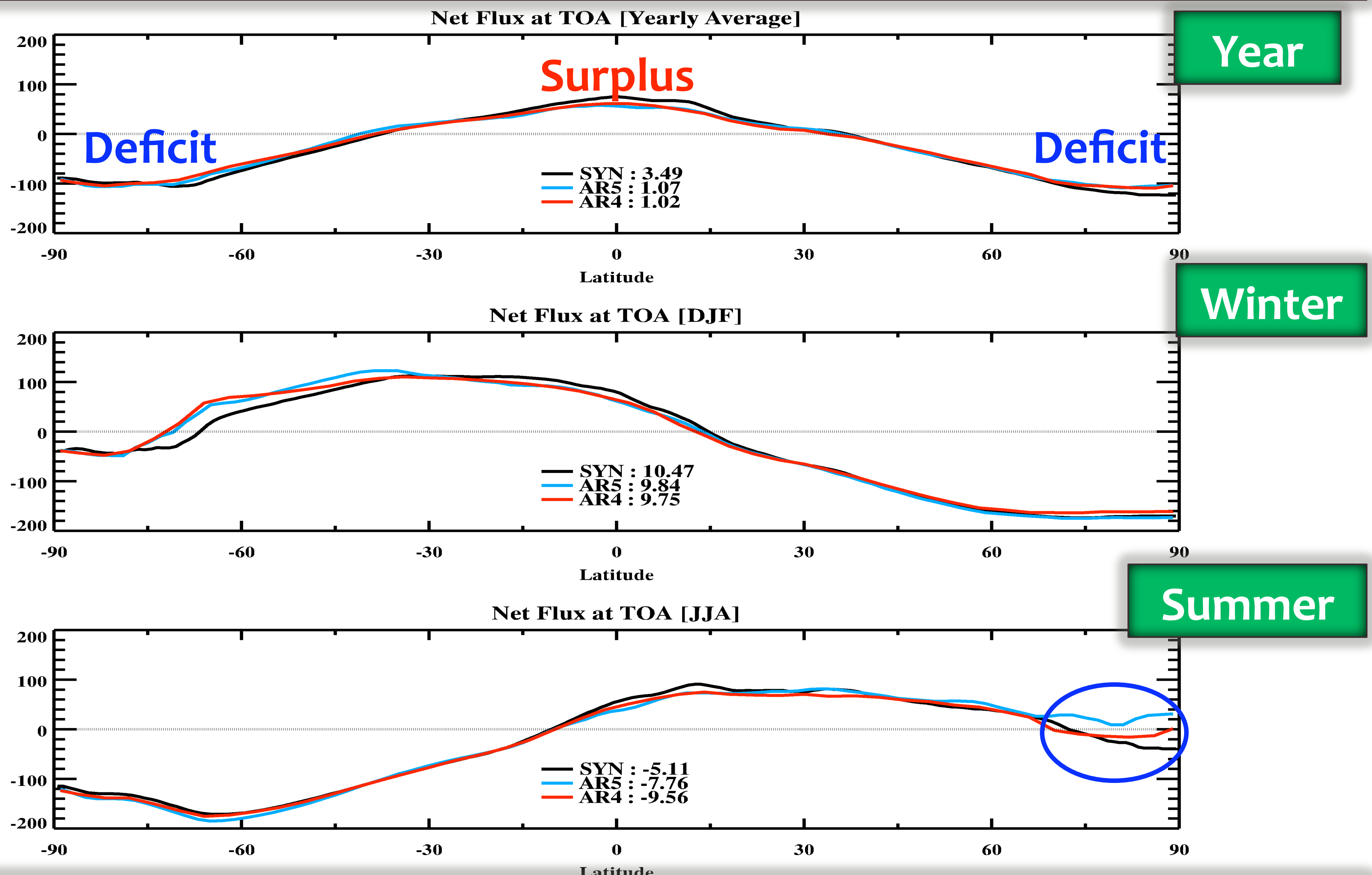
**Summer**




There are relatively large differences over Northern Hemisphere, such as central Asia, Arctic region, etc. Their global difference is 2.65 $Wm^{-2}$

# Latitudinal NET Flux Comparison between CERES, AR4 and AR5




The annual mean of CERES is 2.5 $Wm^{-2}$ more than AR4 and AR5.

During summer, large differences over Arctic. AR4 is 4.5 $Wm^{-2}$ less

# Summary and Conclusions

1) Cloud Fraction Comparison

During Winter, Model overestimated CFs in Arctic and Tropics, but underestimated CF in Southern mid-Latitudes.

Summer comparison is same as winter, such as model overestimated CFs in Tropics, Sahara desert and Antarctic, underestimated CF in Southern mid-lat (and Arctic region-only difference).

2) Radiation Comparison

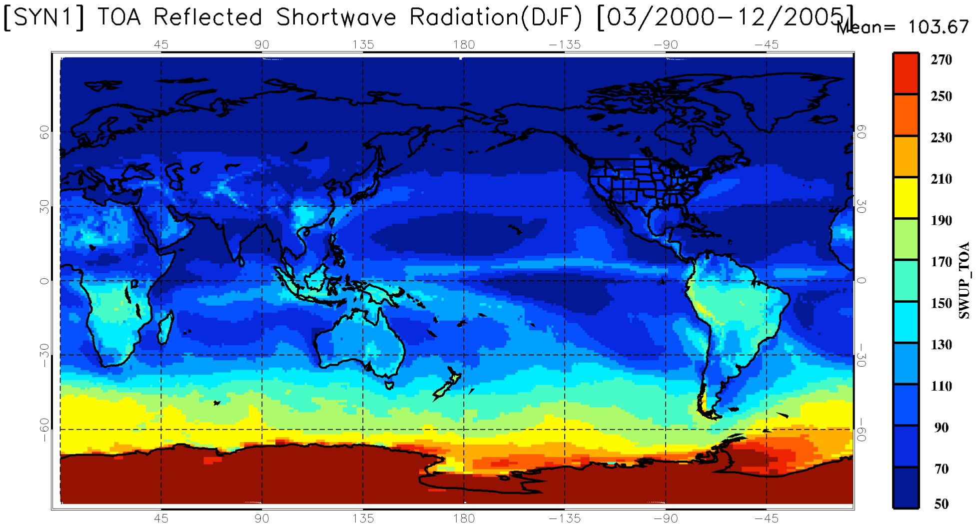
The AR4 and AR5 simulated TOA OLR and SW fluxes agree with CERES observations within a few $Wm^{-2}$.

In general, Winter comparison is better than summer Comparison.

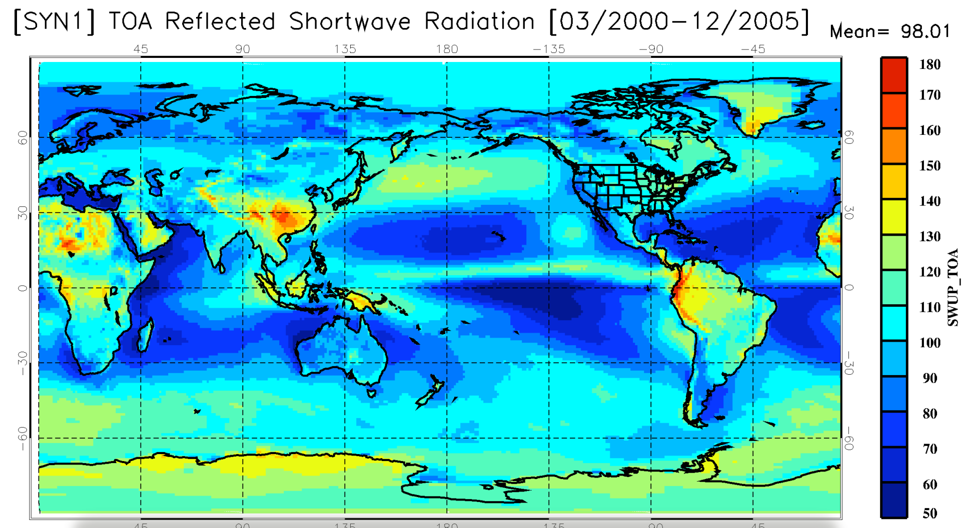
Southern Hemisphere comparison is better than Northern Hemisphere Comparison (due to more land surfaces)

# Thanks for your attention

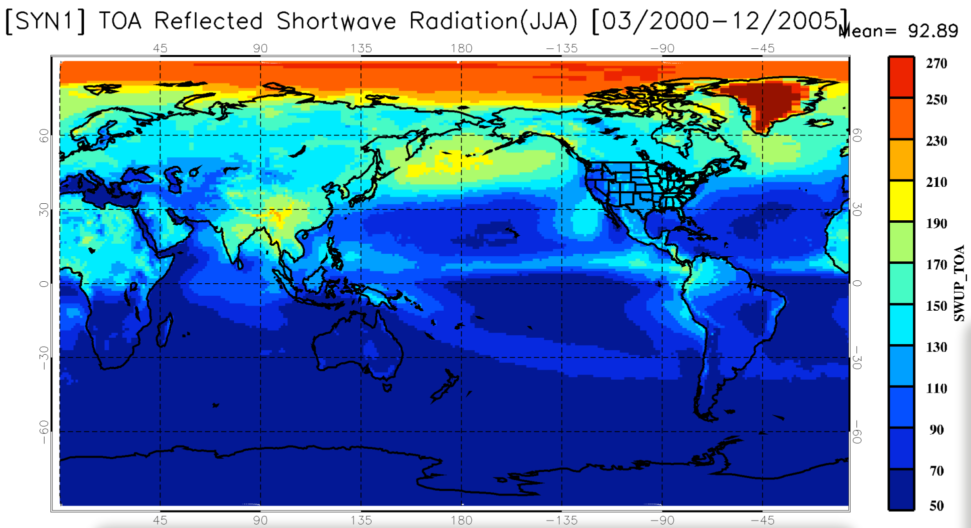
## “Winter” DJF




## SYN1 [Observation] SWUP

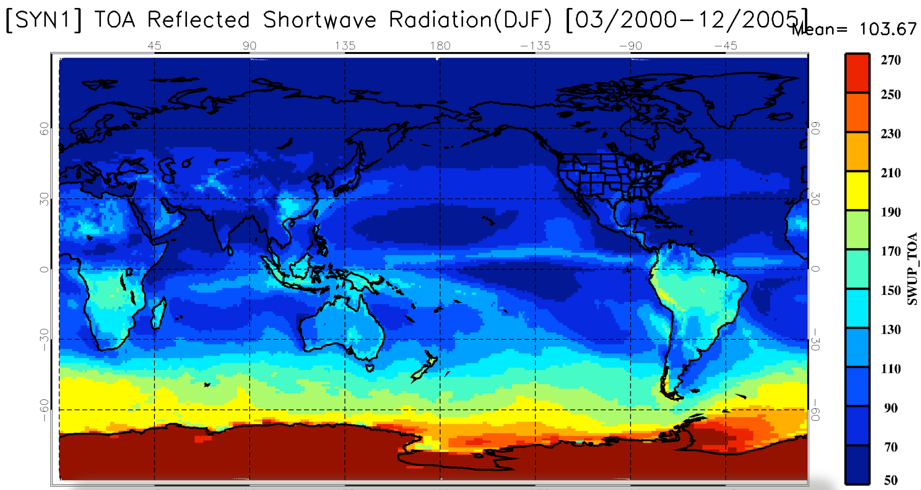


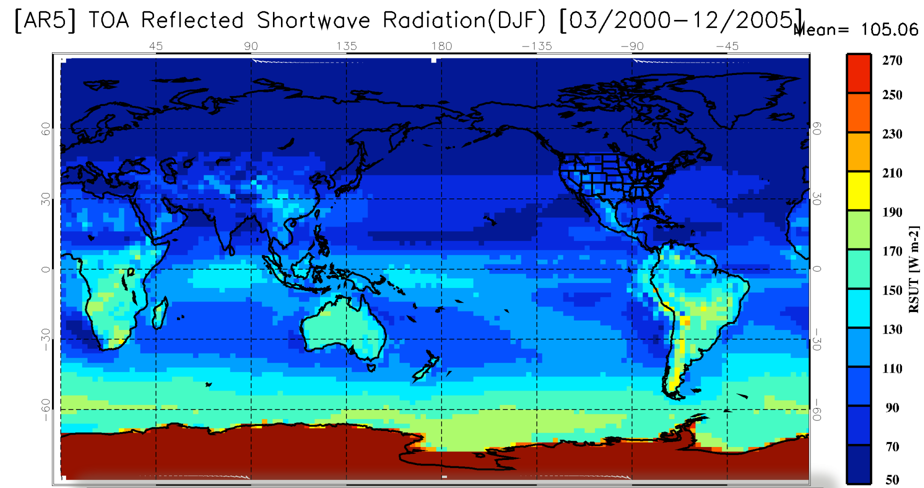

## All-Year




## “Summer” JJA

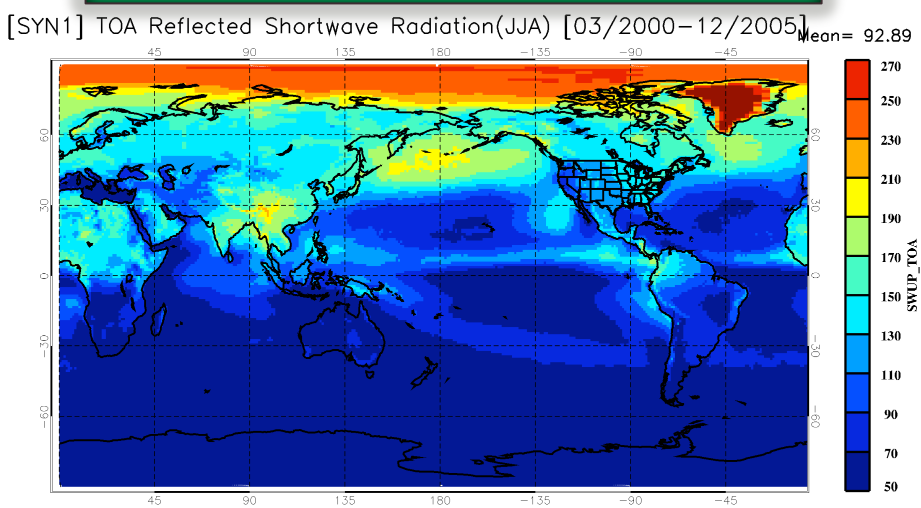
We see our highest amounts of reflection around continually snow covered regions, Greenland and the Antarctic. Particularly mountainous regions and deserts also provide high amounts of reflectivity, Andes mountains and the Gobi/Sahara deserts.

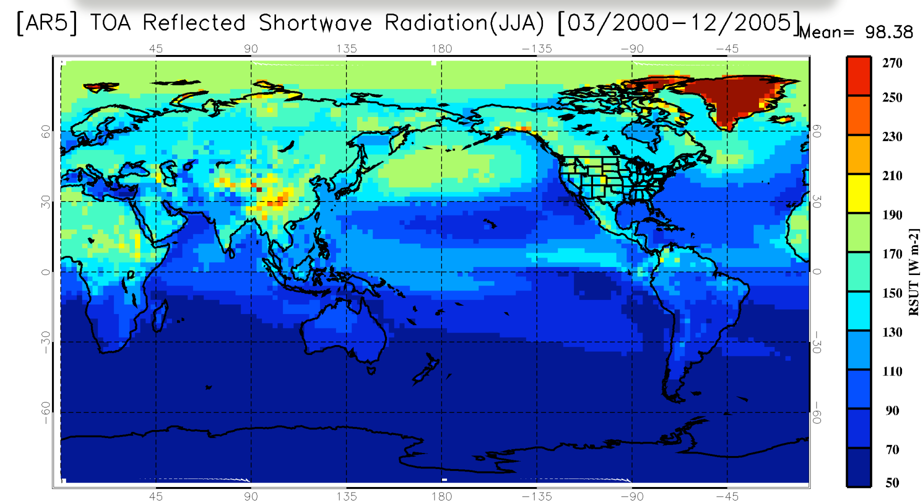



Observation – SYN1

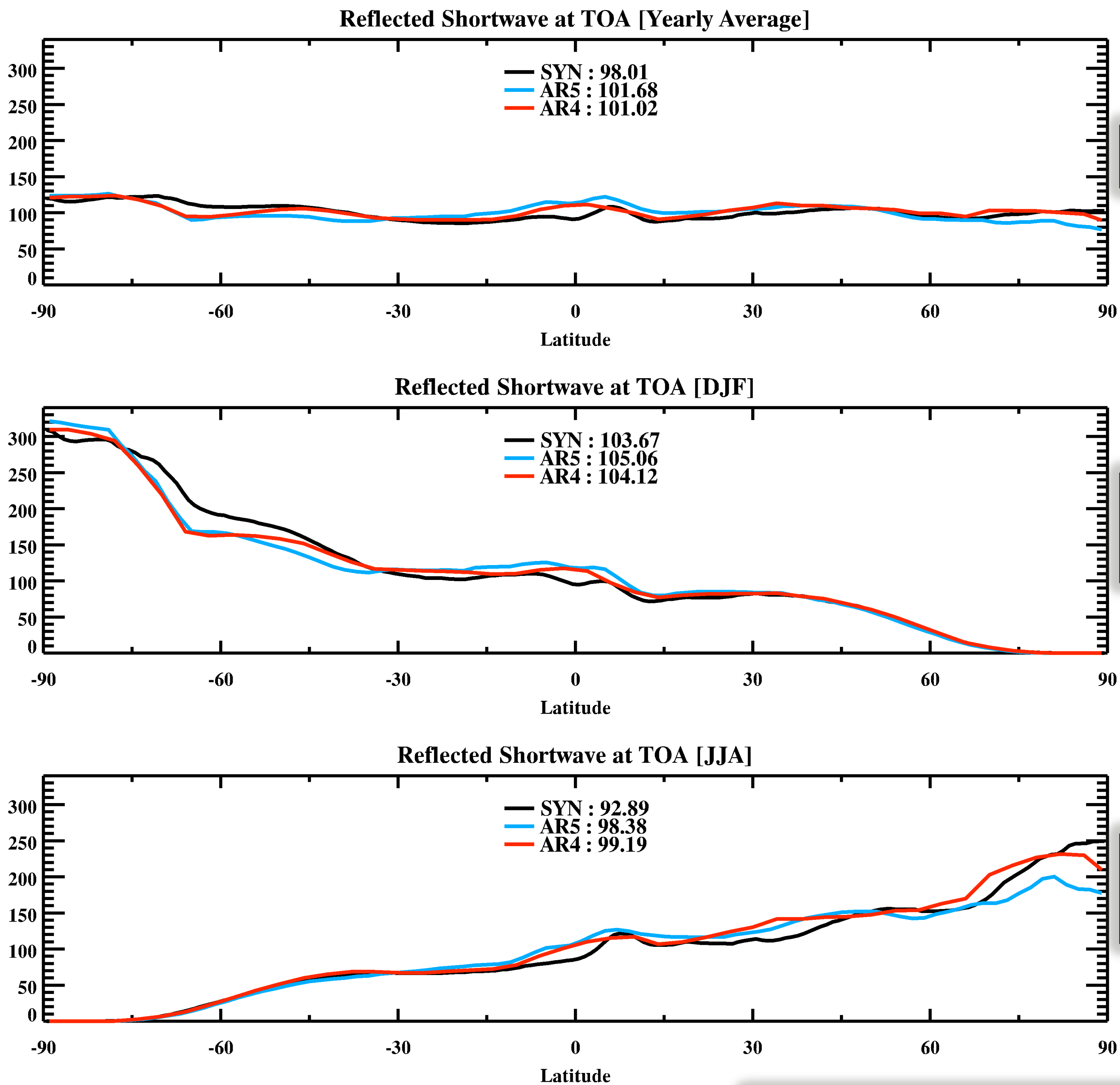
Model – AR5




SWUP-TOA

The model captures the extremes well, but tends to underestimate the local regions surrounding these maxima. Overestimating the desert regions but underestimating the Andes.



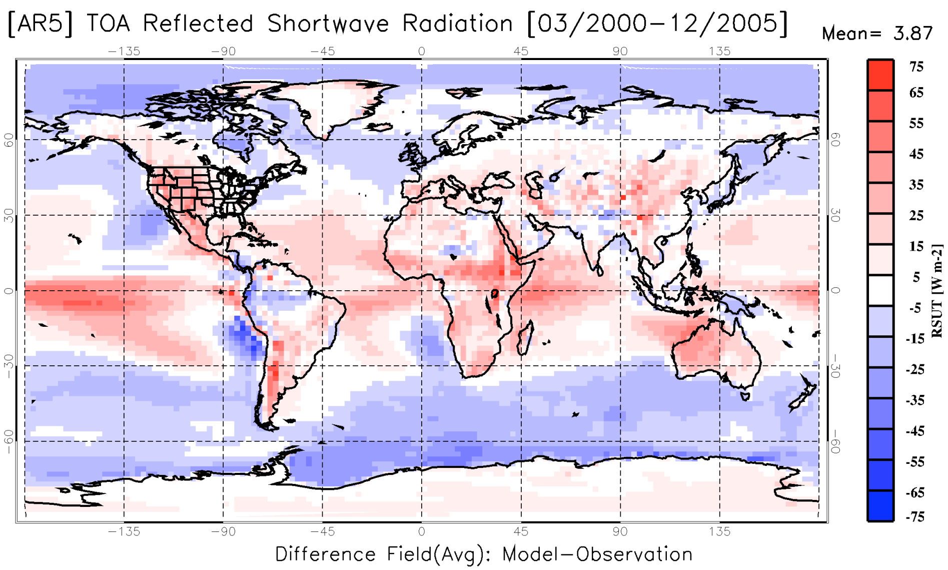

All-Year

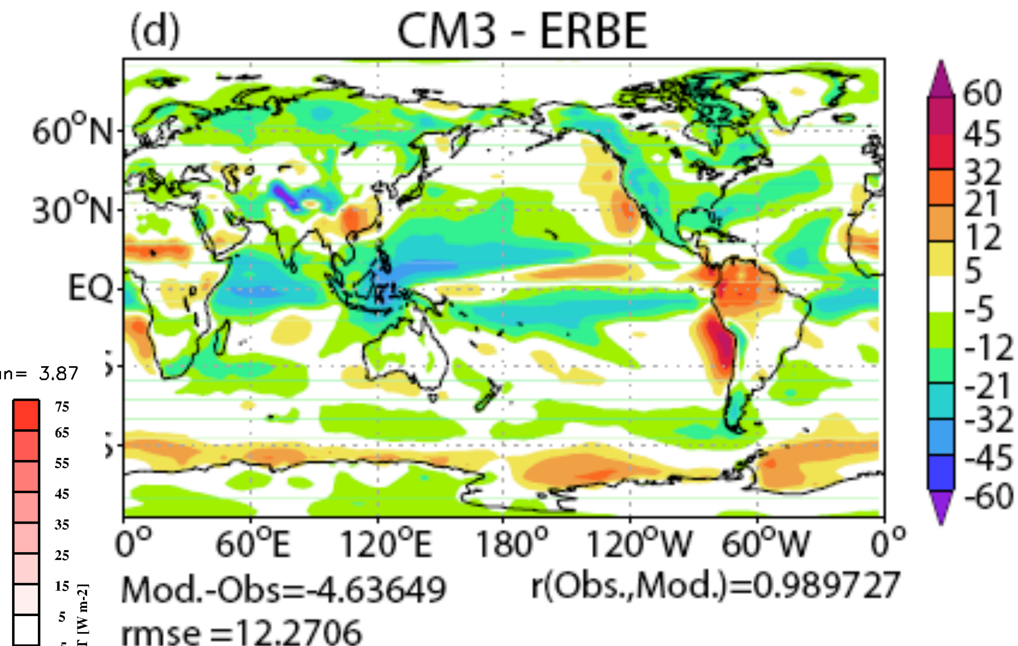
“Winter”
DJF

“Summer”
JJA

# Model Comparison - SWUP

## GISS – Reflected SW




## GFDL – Absorbed SW (above)

## NCAR-SW Cloud Forcing (below)

“We absorb too much SW in the southern midlatitude storm tracks (see Trenberth and Fasullo 2010) and the marine stratocumulus regions, and since we have to be in global radiation balance before we can do an IPCC coupled model run, we have to tune our models to reflect too much SW in the tropics. This is an example of a problem that GCM groups have been aware of for a long time. But solving it is difficult - it depends on a good simulation of ocean boundary layer clouds, which is very hard to do (or else we would have solved it already).” ~Anthony Del Genio (via e-mail)

CAM5 bias